ENERGY 2020
Documentation

Volume 1

Overview

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Overview of ENERGY 2020

OVERVIEW OF ENERGY 2020

THE BASIC VERSION OF ENERGY 2020

ENERGY 2020 is a multi-sector energy analysis system that simulates the supply, price and demand for all fuels. It can be interactively configured to any level of detail with regard to the energy system by changing the structure of the model. Additional sectors or modules from other non-ENERGY 2020 related models (such as a macroeconomic model) can be incorporated directly into the ENERGY 2020 framework. This flexibility allows the model to evolve over time in response to the changing objectives of the decision maker.

ENERGY 2020 OVERVIEW
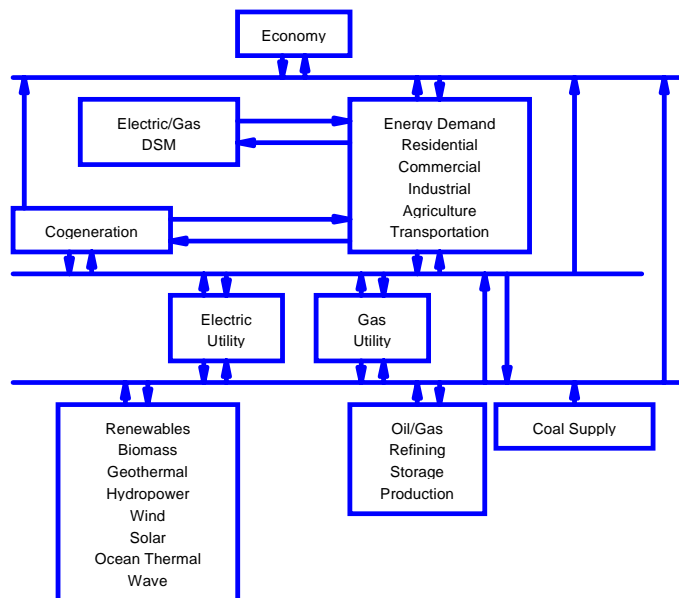

Figure 0.1

ENERGY 2020 differs from many of the utility models in use today. ENERGY 2020 does not contain elasticities and obscurely specified parameters. To make model results understandable and realistic, a one-to-one relationship always exists between the model and the real world. For example, customer responses to relative price changes is not modeled using price and income

elasticities. Instead, all the factors that determine the choices one makes when a purchase is made such as the amount of money you have, what your preferences are, and how well informed you are about other prices are all explicitly modeled in ENERGY 2020.

ENERGY 2020 is made up of model sectors that can be modified, expanded or deleted to suit individual client needs. Figure 0.1 illustrates the current model configuration. Common to all versions of ENERGY 2020 is an economy sector where economic growth rates are determined. The economy sector can be run either interactively with the Regional Economic Models, Inc. (REMI) economic model or with any good twenty year economic forecast.

The ENERGY 2020 model runs under the PROMULA simulation system. PROMULA allows mainframe models to run on microcomputers. It also allows programs written in any other language to run simultaneously with it. PROMULA provides sophisticated, but easy-to-use and fast database manager, program editor, decision tree, simulation, statistical/regression, graphics, and report generator capabilities. Programs written for any other computer can be automatically converted to run quickly on a microcomputer. With minimal additional effort sophisticated menus and database capabilities can be added.

Energy demand itself is created from five model sectors: Residential, Commercial, Industrial, Agriculture and Transportation. Most versions of ENERGY 2020 have at least the first three sectors operating; it is not uncommon to use all five. In addition to these basic demand model sectors, two more sectors - electric and gas DSM and the Cogeneration sectors, modify the demand sectors. All sector demands are influenced by DSM and most, especially industrial, are modified by cogeneration capability.

Demand is dynamically simulated by end-use and economic sector for all fuels (electric, gas, oil, LPG, coal, biomass and solar). The disaggregation of end-use and economic sector can be as detailed as the user can accommodate - a "typical" model has a few residential and commercial classes, industrial demand divided into two digit SIC code subclasses, transportation demand modeled by class and mode, and about six to eight end-uses for each class. Oil, gas, alcohol, and electric vehicles are modeled. Gas-refrigeration and air-conditioning are standard end-uses. Marginal and average energy intensity at both the process and device level are determined. ENERGY 2020's unique capability to model how consumers make fuel and efficiency choices in the face of personal preference, price, and utility incentives is critical to DSM and competitive analysis.

Independent power producer and cogenerator behavior (across ten technologies) as well as pollution generation (across eight pollutants) both at the end-use and supply level are dynamically calculated. Additional pollutant types and technologies to represent land and water pollution can be added as desired.

The other half of the energy demand market, the supply sector, is modeled in several parts as well, depending on client needs. The two most common are the electric and gas utility sectors which generate energy used to meet energy demands. The renewable resources sector usually impacts the electric utility sector but also affects the demand sectors as well through such things as solar water heat and biomass process heat. Less used, but also available are a complete oil and gas refining sector which tracks the exploration, refining, production and storage of oil and

gas as well as a similar sector for coal supply. Any supply sectors not specifically modeled are captured in a generic supply sector that generates fuel prices and availability. For example, a common supply sector configuration would be an electric utility sector, a gas utility sector and a generic supply sector for oil and coal supplies.

For electric and gas utilities (separate or combined), ENERGY 2020 internally and self-consistently simulates sales, load (by end-use, time-of-use, and class), production (across thirty-six dispatch types), demand-side management (by technology), forecasting, capacity expansion (new generation, independent-power-producers, purchases, and DSM), finance, and rates (by class, end-use, and time-of-use). Utility bypass and transportation are internally estimated. Supply dispatch order can be pre-specified, based on variable costs, or based on attributes (as in the case of pollution minimization). The dispatch process can be modeled by fast advanced derating, chronological-probabilistic, or linear programming methods. Multiple service areas are simply linked together. Firm contract and spot market interactions can be specified. A version of ENERGY 2020 can analyze utility deregulation dynamics.

ENERGY 2020 addresses both demand-side and (conventional and renewable-fuel) supply option impacts on financial health, rates, and the customer. Peak and off-peak avoided, marginal, and incremental costs are calculated. Transmission, distribution, and cogeneration issues are also addressed. ENERGY 2020 provides a complete, realistic description of supply and demand processes, options, and issues that must be considered for adequate IRP and LCP assessment. Over 250 pre-specified scenarios/options can be combined and easily modified to test almost any scenario imaginable. A summary of the possible output generated by ENERGY 2020 is shown in Table 0.1 ENERGY 2020 Outputs.

ENERGY 2020 is automatically calibrated to a specific service area or region with minimal data requirements - much of the data are on default databases specified by state. Model input routines provide automatic error checking and input screen display templates of standard utility reporting forms (for example, FERC Form 1, EIA Form 412, and/or Annual Financial Reports). Model output can be displayed in the same standard report

Table 0.1 ENERGY 2020 Outputs

Basic Data
Balance Sheet
Sources and Uses of Funds
Income Statement
Capacity
Generation
Sales
End-Use Loads

Comparison Studies
Service-Area/Employment Impacts
DSM Market Dynamics

Pollution Emissions
Rate Schedule Effects
Gas versus Electric Market Dynamics
Alternative Regulatory Treatment

Standard Studies
Cost Benefit Analysis with Externalities
Uncertainty/confidence Analysis
Dynamic Impact Analysis
Perspective Analysis

Special Studies
Mergers
Acquisitions
Deregulation
Decentralization

formats or with high resolution color graphics. Model results can be sent to a printer or plotter. Data files can be read and manipulated using standard spreadsheets such as EXCEL and Lotus 1-2-3.

ENERGY 2020 has an uncertainty package called HYPERSENS to aid the user in policy testing.   HYPERSENS quantifies the impacts of conservation technology uncertainty on utility/consumer cost/benefits where the components of the cost/benefit measure may be the price of electricity, revenue requirements, capacity requirements, and energy costs per consumer unit. Other measures can be calculated as determined by the user. The uncertainty analysis uses the efficient Latin-Hypercube Sampling approach developed at Los Alamos National Laboratory. Uncertain parameters can be described by any arbitrary distribution. Input parameters are varied simultaneously to capture the more realistic "all-else-not-equal" conditions.

ENERGY 2020 also has attribute and post-processing capabilities. Although ENERGY 2020 is not an optimizing model, users can define their "objective function" for model results - stable rates, reduced peak demand, maximum return on investment, etc. Combinations of attributes can be weighted to obtain composite measures for ranking scenarios. These multi-attribute functions can be used with HYPERSENS to find the optimally robust strategy to achieve the desired objectives, in effect, determining the "optimal" path. Added post processing capabilities allow the user to manipulate model generated data to automatically perform unique analyses.

ENERGY 2020 calculates the market penetration, sales/load impacts, program costs, reliability impacts, revenue impacts, cost/benefit figures of merit, etc. of DSM options. Peak and off-peak avoided, marginal, and incremental costs can be calculated. T&D and cogeneration issues are also addressed. Peak clipping, valley filling, load shifting, strategic conservation, and strategic load growth (by day and season) options can be specified. Consideration of focus (small versus large customer) and level (aggressive versus limited implementation) are part of the DSM option

selection process. ENERGY 2020 provides a complete, realistic description of the demand processes, options, and issues that organizations must consider for adequate demand-side option assessment.

In summary, ENERGY 2020's integrated planning framework simulates the dynamics interactions within the energy sector under various plans and uncertainties (scenarios). The ENERGY 2020 framework can be automatically calibrated, using generally available data, and modified to represent any particular energy source, utility company, or geographical area. It then becomes a descriptive tool that dynamically simulates current and future conditions. It provides a laboratory in which planners can examine the long-range implications of programs and policies. Table 1.2 provides an overview of ENERGY 2020's features.

ENERGY 2020 IS AN END-USE (DISAGGREGATE) MODEL

Historically, energy use has been forecast either by customer class or rate class. Further delineation based on energy use was not considered. But many models, including ENERGY 2020 now forecast energy use by customer-designated end-uses such as space heating and lighting. End-use models sometimes seem needlessly complex to those working with the more general econometric models. Although both types of modeling have strengths and weaknesses, end-use models are gaining in popularity for several reasons. First, they are often required in many states. Utilities see them as a way to get to know their customers better in an increasingly more competitive and customer-centered energy market. Regulators often prefer them for their ease of policy testing, particularly DSM policies that are difficult to handle with econometric models.

Table 0.2: General ENERGY 2020 Model Features

- *Integrates energy supply, price, demand, economy, and regulation. Includes all fuel demand and supply model with detailed electric and gas utility capability. Has detailed Cogeneration and Qualified Facility sectors. Simulates all decision or strategy points of energy supplier and consumer (both short and long-term). Captures the feedback dynamics between Utility, Demand, Economy and Regulation sectors.*

- *Analyzes Mid to Long-Term Planning. Simulates continuous dynamics of supply, price, load, pollution emissions and end-use demand from 1975 - 2020 time frame. Includes critical feedback shown by NERC as most important to forecasting.*

- *Performs cost-benefit analysis of DSM programs and any scenario with externality pollution costs, and uncertainty.*

- *Provides both least-cost and consumer-preference decision criteria.-Performs historical validation and automatically calibrates to unique utility service area conditions. Uses publicly available data.*

- *Automatic uncertainty and sensitivity analysis produces actual confidence intervals rather than high and low cases.*

- *Provides scenario database for user-specified definition and initiation of scenario packages. Calculates decision-maker preference-function for each scenario.*

- *Simulates pollution generation from both consumer and utility end-use (Typically eight pollutants with impact-weighted indices.)-Allows interactive modification of model structure to include additional or alternative sector representations. Model is designed to ease modification, extension and scenario additions.*

- *Allows easy execution and comparison of multiple runs/scenarios. Provides interactive input editing, output review, report generation, and mathematical transformations.*

- *Can integrate with a client's existing analysis tools written in other languages.*

- *Over 250 experience-years of model usage/development at federal, state, energy company, and utility level. (Early version still used for all U.S. DOE National Energy Plans.) Model used for energy policy and planning by other 27 states and Canadian provinces. Over $15 Million spent on model development and testing.*

- *Reviewed favorably in studies by the California Energy Commission, Barakat and Chamberlin, Inc., Southern Company Services, Inc., and the National Academy of Sciences (FOSSIL2/IDEAS).*

- *Model can be freely given to others for review and critique (or cooperative policy development between adversarial groups). Code is machine independent(runs on personal computer or mainframe).*

Their clear advantage in policy testing is the second reason causal models are gaining popularity. For example, to determine the impact of a rebate on high efficiency electric hot water heaters it is necessary to know the energy use of existing hot water heaters (is it large or small relative to total load), to estimate the impact of the policy. If electric hot water heaters contribute only minutely to total load, then DSM programs designed to minimize this already small load will not have a significant effect on utility sales.

The third reason for the gaining popularity of end-use models is the availability of structural enhancements that allow model changes in the causes of energy demand, and not simply changes in demand itself. For example, if you have a residential electric econometric forecast and you are implementing a policy encouraging fuel switching, all you can do is reduce electric load by some estimated amount. With ENERGY 2020, there is the gas forecast, the percentage of demand that is substitutable as well as prices, and previous energy decision behavior. It is possible to directly model the change in the system and have the energy sales change in response to the policy. Using the water heating example above, other effects that would be captured by ENERGY 2020 include fuel switching from natural gas to electric hot water as the price of the electric hot water heater is made more economic by the rebate. Not only is the change in energy demand simulated with a causal model, but the composition of the change is simulated as well. Also, with an integrated end-use model, there would be consistency between the natural gas and electric assumptions, difficult to achieve with separate forecasts.

Finally, the analyst can feel comfortable with the simulation results of a causal model because there is an understanding of why demand changes occurred. If residential energy demand is projected to grow by two percent per year, an econometric model usually provides only a couple

of variables - number of customers and use per customer. With an end-use model, the analyst can see, for example, that the residential energy growth is determined by a growth in space heating demand (a fuel switch from natural gas to electric), a decrease in lighting and refrigeration demand (due to increased efficiencies) and an increase in miscellaneous electricity use.

ENERGY 2020 IS A CAUSAL MODEL

Causal models are made up of variables that allow the user to directly relate changes in the real system to changes in the model. Causal models model cause and effect relationships. This is significantly different from models that look at variable correlation, with no implied causality. For example, weather and energy use are correlated. Given temperature we can make some determination about demand. This is true of both causal and correlation models. If temperatures rise in the summer, demand should rise as well. The causal model has structure which causes the temperature rise to increase the demand for energy, the econometric model determines only that there exists a relationship between the two variables. With a correlation, direction does not matter. It is just as true to say that the increase in demand correlates with an increase in temperature as it is to say an increase in temperature correlates with an increase in demand. However, it would be ludicrous to imply that changing demand causes changing weather - causality has direction.

This causal model has structure that mimics the real world allowing the analyst to describe how energy use changes. For example, energy use in ENERGY 2020 depends upon device and process efficiencies and market share among other variables. Each of these variables has a real world counterpart and can be modified to reflect changes, either naturally occurring or through policy implementation.   With econometric models, these changes are all captures with an elasticity - a catch-all term that is hard to modify to reflect structural or policy changes. Changes in a causal model "work through" the model and the analyst can see exactly what effects these changes have.

This transparency becomes particularly important when policies are being tested. Secondary and tertiary effects are picked up with a causal model that might be overlooked in other modeling endeavors. For example, a policy increasing the efficiency of electric air conditioning can lower peak demand and prices. However, these lower prices have effects of their own, including fuel switching into electric and possibly lower device and process efficiencies in the non-policy end-uses. These effects are not captured in models with incomplete market structure.

Finally, using a causal model helps the analyst provide justifications for adjustments to the model or forecast. Instead of simply lowering the forecast because it is "too high", the analyst can identify specific variables which may be highly uncertain - fuel prices, technology constraints, behavior variables - and adjust accordingly.

ENERGY 2020 REPLICATES HISTORY

It is the structure of the ENERGY 2020 model, representing how decision makers act, rather than exogenous data, that primarily determines the model results. The ENERGY 2020 structure

allows the model to reproduce history. If a model cannot reproduce history there can be no confidence that it can properly simulate the future. Without historical tests it is impossible to determine whether feedback is properly incorporated, what is missing, or what is improperly specified. Other models cannot reproduce history because real-world systems (e.g. energy consumers and suppliers) fail to follow the models' idealized, optimal, and generic rules. Each real-world case study shows that "exceptions-to-the-rules" affected the past and will determine the future.

Because ENERGY 2020 simulates how participants in an energy system make decisions, it is able not only to reproduce (and explain) history, it can simulate how decision makers will act when they are faced with policies/conditions for which there is no historical precedent. Most scenarios conceived today fall in to the "no-precedent" category.

ENERGY 2020 can be calibrated to any service area or region with publicly-available data. Its internal national and state databases contain historical economic, price, and demand data by economic sector, fuel, and end-use. Utility data can be entered via templates of standard utility reports or, if available, electronically transferred. Further, any data the user does not enter or is not already on the database will be provided "synthetically." The default databases contain not only generic data, but also regional data that is modified to be compatible with the data provided by the user. For example, if the user only knows the system peak and annual customer class sales, the input routines will generate estimated end-use load shapes by class by appropriately scaling detailed state or regional data. As the user adds more data, less "default" data is synthetically created. The data set evolves as better data is added to it. ENERGY 2020 is often used for analyses where the user-specific data is limited but answers are critically needed.

OVERVIEW OF THE ENERGY 2020 DEMAND MODEL

The demand sector of ENERGY 2020 represents the service area by disaggregating the four economic sectors: residential, commercial, industrial and transportation into subsectors based on energy end-use. As many or as few subsectors can be supported as desired. The Commercial sector may be divided into subsectors that include offices, restaurants, retail establishments, groceries, warehouses, elementary and secondary schools, colleges, health fields and hospitals, hotels and motels, and a miscellaneous buildings category. The industrial sector often is divided into subsectors by two-digit SIC code. The transportation sector models the transportation demands for each of the sectors; residential, commercial, and industrial. The residential sector may be divided into single family, multi-family and mobile homes.

Multiple end-uses (including transportation and feed stocks) and multiple fuels are detailed. Currently, the commercial sector is configured to have eight end-uses: Primary Heat, Refrigeration, Lighting, Water Heating, Cooking, Ventilation, Air Conditioning and Miscellaneous Demands. The industrial sector has four end-uses: Process Heat, Motors, Lighting, and Miscellaneous Demands. Fuel choices include natural gas, oil, coal biomass, solar, electric and LPG. Cogeneration, fungible demands (fuel switching), municipal resale demands, and power pool resale demands are also determined by the.

A few basic concepts are crucial to an understanding of how ENERGY 2020 models the energy system. The capital stock driver, the modeling of energy efficiency through trade-off curves, the fuel market share calculation, utilization multipliers and the cogeneration module are discussed below in abbreviated form. More detailed discussions can be found in Chapters 2, 3 and 4. Figure 0.2 illustrates the demand sector interactions. Table 0.3 shows the typical features of the demand sector.
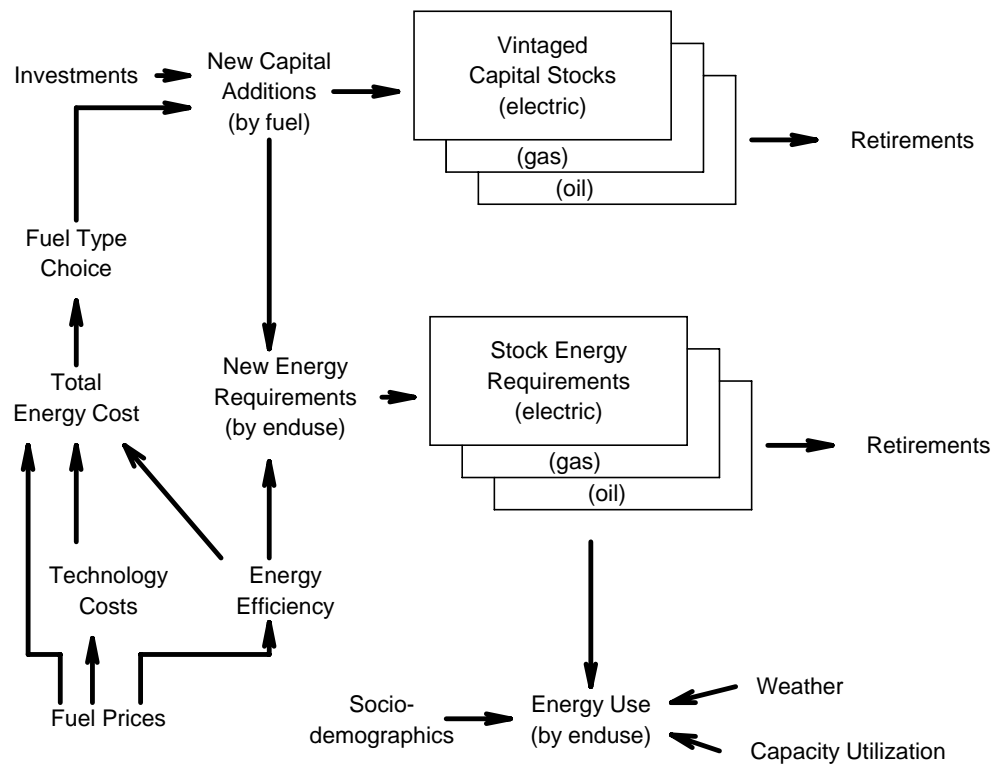

Figure 0.2

Energy Demand as a Function of Capital Stock

ENERGY 2020 assumes that energy demand is a consequence of using capital stock in the production of output. For example, the industrial sector produces goods in factories which require energy for production; the commercial sector requires buildings to provide services; and the residential sector needs housing to provide sustained labor services. The occupants of these buildings require energy for heating, cooling, and electromechanical (appliance) uses.

The amount of energy used in any end-use is based on the concept of energy efficiencies. For example, the energy efficiency of a house along with the conversion efficiency of the furnace determine how much energy the house uses to provide the desired warmth. The energy efficiency of the house is called the capital stock energy or process efficiency. This efficiency is primarily technological (e.g. insulation levels) but can also be associated with control or life-style changes (e.g. less household energy use because both spouses work outside the home.) The furnace efficiency is called the device or thermal efficiency. Thermal efficiency is associated with air conditioning, electromotive devices, furnaces and appliances.

The model simulates investment in energy using capital (buildings and equipment) from installation to retirement through three age classes or vintages. This capital represents embodied energy requirements which will result in a specified energy demand as the capital is utilized, until it is retired or modified.

Table 0.3 Demand Sector Features

- *Simulates process and device-side decisions.*

- *Trades off capital and efficiency with fuel prices dynamically. Incorporates both least-cost and consumer-preference energy efficiency curves.*

- *Allows testing of any major scenario (e.g., efficiency standards, subsidies, low interest loans ,energy taxes, cost sharing, tax credits, risks, indirect costs, expending or capitalization of conservation costs, technological advances, environmental regulations, energy shortages).*

- *Simulates short-term effects such as budget constraints and temperature sensitive loads.*

- *Includes socio-economic change (female labor-participation, multi-family housing) and other non-energy price effects.*

- *Simulates marginal investments, fuel switching, and fuel conversions.*

- *Allows arbitrary number of end-uses (Example: primary/process heat, cooking, drying, hot-water, lighting, air conditioning, refrigeration, miscellaneous electromotive, feedstock, etc.)*

- *Allows arbitrary number of energy consuming sectors*

- *Simulates energy demands for all fuels (standard: gas, oil, high-sulfur coal, low-sulfur coal, biomass, solar, electric).*

- *Simulates cogeneration investment, construction, and usage.*

- *Simulates inter/intra-regional energy demands.*

The size and efficiency of the capital stock, and hence energy demand, change over time as consumers make new investments and retire old equipment. Consumers determine which fuel and technology to use for new investments based on perceptions of cost and utility. Marginal

trade-offs between changing fuel costs and efficiency determine the capital cost of the chosen technology. These trade-offs are dependent on perceived energy prices, capital costs, operating costs, risk, access to capital, regulations and other imperfect information.

ENERGY 2020 formulates the energy demand equation causally. Rather than using price elasticities to determine how demand reacts to changes in price, ENERGY 2020 explicitly identifies the multiple ways price changes influence the relative economics of alternative technologies and behaviors, which in turn determine consumers' demand. In this sense, price elasticities are outputs, not inputs, of ENERGY 2020. The model accurately recognizes that price responses vary over time, and depend upon factors such as the rate of investment, age and efficiency of the capital stock, and the relative prices of alternative technologies.

Device and Process Energy Efficiency

The energy requirement embodied in the capital stock can be changed only by new investments, retirements, or by retrofitting. The efficiency with which the capital uses energy has a limit determined by technological or physical constraints. The trade-off between efficiency and other factors (such as capital costs) is depicted in Figure 0.3. The efficiency of the new capital purchased depends on the consumer's perception of this trade-off. For example, as fuel prices increase, the efficiency consumers choose for a new furnace is increased despite higher capital costs. The amount of the increase in efficiency depends on the perceived price increase and its relevance to the consumer's cash flow.
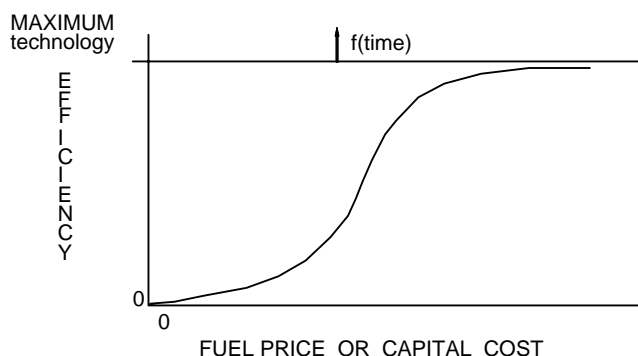

Figure 0.3 Efficiency/Capital Cost Trade-Off

The standard ENERGY 2020 efficiency trade-off curves are called consumer-preference curves because they are estimated using cross-sectional (historical) data showing the decisions consumers made based on their perception of a choice's value. Many planners are now interested in measure-by-measure or least-cost curves which use engineering calculations and discount rates to show how consumers should respond to changing energy prices. Another analysis

focuses on the technical/price differences in alternative technologies and the incentives needed to increase the market-share or market penetration of a specific technology. This perspective on the choice process uses market share curves. ENERGY 2020 allows the user to select any of these three types of curves to represent the way consumers make their choices. Shared savings, rebate, subsidy programs, etc. can be tested using any of the curves.

Cumulative investments determine the average "embodied" efficiency. The efficiency of new investments versus the average efficiency of existing equipment is one measure of the gap between realized and potential conservation savings.

ENERGY 2020 uses saturation rates for devices to represent the amount of energy services necessary to produce a given level of output. Saturation rates may change over time to reflect changes in standard of living or technological improvements. For example, air conditioning has historically increased with rising disposable incomes. These rates can be specified exogenously or can be defined in relation to other variables within the model (such as disposable income).

The Market Share Calculation

Not all investment funds are allocated to the least expensive energy option. Uncertainty, regional variations, and limited knowledge make the perceived price a distribution. The investments allocated to any fuel type are then proportional to the fraction of times one fuel is perceived as less expensive (has a higher perceived value) than all others. This process is shown graphically in Figure 0.4.
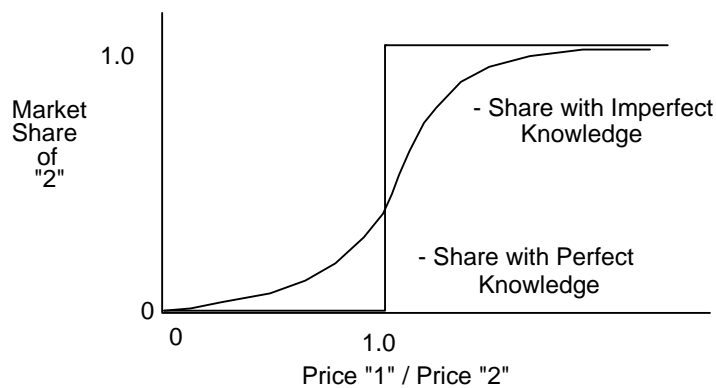
Figure 0.4: Market Share Dynamics

Short Term Budget Responses

A short-term, temporary response to budget constraints is included in ENERGY 2020. Customers reduce usage of energy if they notice a significant increase in their energy bills. The customers' budgets are limited and energy use must be reduced to keep expenditures within those limits. These cut-backs are temporary behavioral reactions to changes in price, and will phase out as budgets adjust and efficiency improvements (true conservation) are implemented. This causes the initial response to changing prices to be more exaggerated than the long-term response, a phenomenon called "take-back" in studies of consumer behavior.

Accounting for Fungible Demand

Some furnaces and processes can use multiple fuels. That is, they can switch almost instantaneously between, for example, gas and oil or coal and biomass as prices or the market dictates. Energy demand that is affected by this short-term fuel switching phenomena is called fungible demand. ENERGY 2020 explicitly simulates this market share behavior.

Modeling Cogeneration

Most energy users meet their electricity requirements through purchases from a utility. Some users (industrial and commercial) can, however, convert some of their own waste heat into usable electricity when economics warrant such action. Other users (residential and commercial) can purchase self-generation energy sources such as gas turbines and diesel-generators.
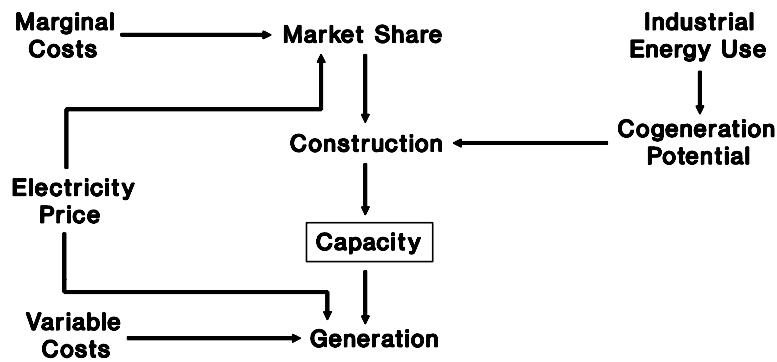
Figure 0.5: Cogeneration Concepts

In the ENERGY 2020 system, all energy used for heating is a candidate for cogeneration. The cost of cogeneration is the fixed capital cost of the investment plus the variable fuel costs (net of efficiency gains). This cogeneration cost is estimated for all fuels/technologies and compared to the price of electricity. The marginal market share for each cogeneration technology is based on this comparison. Figure 0.5 shows a simplified overview of the cogeneration structure.

Cogeneration is restricted to consumers who directly produce part of their own electricity requirement. Qualifying Facilities (QFs), which generate power for resale to the utility, are considered independently by ENERGY 2020.